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(RCA)

Nas 5-10470

ADDENDUM TO

QUARTERLY TECHNICAL REPORT NO. 7

SUMMARY REPORT

NIMBUS-D SPARE STORAGE MODULE

TESTS AND ANALYSIS

Cat. 03

N70-27139

PREFACE

This report encompasses all the activities pertaining to Spare Storage Modules 028, 031, and 032 from October 15, 1969 to January 13, 1970. Test data obtained prior to October 15, 1969 are contained in Quarterly Progress Report No. 7, issued October 15, 1969 under NASA Contract NAS 5-10470.

1. Introduction and Conclusions

During the acceptance testing of spare storage modules 028, 031, and 032, several anomalies occurred which caused a special investigation to be undertaken to determine if the cells were overstressed sufficiently to make them unsuitable for flight use. An analysis indicated the overstresses were not sufficient to cause permanent damage. A special test program was formulated to prove the integrity of the modules. Modules 028 and 032 completed the series of special tests and exhibited normal characteristics throughout. SN 031 suffered what was considered permanent damage during a conditioning cycle and testing was discontinued on this module.

The test history is given in Table I. For the sake of brevity only the tests during which an anomaly occurred and the special tests are shown. A description of the tests and the results can be found in the referenced section. In addition to the special tests, the modules were subjected to the normal series of electrical confidence tests.

During the special test program no unusual trends were detected and the results were normal in every respect. Based on the analysis and the results of the special test program, it is concluded spare modules 028 and 032 have not been degraded and are suitable for normal flight use.

2. Test Description and Results

2.1 During the thermal-vacuum test performed on spare modules 028, 031, and 032 in accordance with TP-SFTV-1846666 the trickle charge control was in the override position when the 3 minimum load orbits were run at 10°C. This resulted in the modules being overcharged at the full charge rate of 1.1 amps. The remainder of the thermal vacuum test was completed prior to the discover of this anomaly.

An analysis of the data showed that during the second and third orbits, the maximum voltage spec of 1.545 volts/cell was exceeded in a number of cells in each module. The module voltage spec of 34.5 volts was exceeded during orbits 2 and 3 as follows:

Module	Orbit	
	2	3
028	35.57	35.76
031	35.73	35.84
032	35.42	35.56

The voltage values indicate that some hydrogen may have been generated in some of the cells. The quantity would be small and would have no permanent effect since the hydrogen will slowly recombine on standing. The temperature rise during the overcharge periods was not excessive and indicates the cells were not overstressed due to temperature.

As a result of the overcharge, NASA directed a special thermal-vacuum test be performed at 10° C consisting of a 15 hour overcharge and 15 minimum load orbits. This test is described in Section 2.3.

2.2 In setting up the spare flight power supply subsystem in the thermal-vacuum chamber for the special test described in section 2.3, two anomalies occurred. The door penetration connectors were incorrectly connected resulting in module S/N 032 being shorted and fusing a pin in the penetration connector. An analysis of the circuitry indicated the module was subjected to currents in excess of 35 to 40 amperes for a period of time probably less than 10 seconds. The connectors on the control module were interchanged resulting in all 3 modules being shorted from the 15 cell tap. In summary, all modules were subjected to high discharge currents through cells 1 to 15 and module S/N 032 was subjected to an additional high discharge current through all cells. The test continuity was maintained and the tests of section 2.3 were performed next.

As part of the vendor acceptance tests all cells are subjected to a discharge current of 30 amps for 9 seconds. Although the cells were subjected to higher loads for possibly a somewhat longer period, it was felt the cells suffered no permanent damage because of the internal construction of the tab connections. Later inspection (section 2.4) confirmed this.

2.3 In order to assess the effect of the overcharge at 10°C (section 2.1) a special NASA directed thermal-vacuum test was performed. The modules were subjected to a 15 hour overcharge test at 300 milliamps 10°C. During this period the voltages were normal and did not exceed 1.521 volts on any cell. Following this test they were subjected to 15 minimum load orbits at 10°C with the trickle charge operative. The voltages and taper charge characteristics were normal. Table III shows the cell voltages immediately prior to when the charge began to taper. The overcharge and high current discharge did not degrade the 10°C, minimum orbit performance.

2.4 Because of the high discharge currents imposed on the modules, (section 2.2) questions were raised as to whether the cells and associated equipment were overstressed and damaged. Therefore, it was decided to remove several cells for disection. Cell # 5 in S/N 028 and cells # 9 and # 14 were removed from S/N 032. These cells were selected for the following reasons: Cell #5 showed a lower than normal resistance between the cell case and module casting and was typical of a cell exposed to one surge of high current. Cells # 9 and # 14 were chosen at random as being typical of cells exposed to two surges of high current.

Cells #5 and # 14 were disected and inspected. There were no signs of the cells being overstressed. The plate tabs were not burned or discolored from overheating. The separator showed no burned or discolored areas due to localized overheating and the appearance of the plates was normal.

The module harness was inspected and showed no signs of overstress. Since the relay and diode were subjected to the high current these were replaced. The relay was disected and inspected visually and electrically. There were no signs of overstress (attached correspondence dated 16 January 1970.)

2.5 While being given a conditioning cycle prior to performing section 2.6 the cells in module S/N 031 were overstressed and testing on this module was discontinued. At the end of the conditioning charge the module was erroneously overcharged at 2 amps for several hours instead of being discharged. With the high charge voltages encountered, it was apparent an appreciable quantity of hydrogen was generated and the cells were not suitable for flight use.

2.6 Following the rework and prior to additional testing, the individual cells in modules S/N 028 and S/N 032 were given an internal resistance or pulse discharge at 30 amps for 9 seconds as further assurance the cells were not degraded by the previous anomalies. The voltage at the 9 second point was normal and compared favorably with the initial values obtained during acceptance tests at the vendor's. The results are shown in Table III.

2.7 A final acceptance test was formulated, in conjunction with NASA, to verify the operation and integrity of spare storage modules SN 028 and S/N 032. This is a thermal-vacuum test consisting of a 48 hour overcharge test with the voltage limit set at 33.58 volts, followed by 30 orbits at 10°C. The cycling procedure was in accordance with the normal load conditions of TP-SFTV-1846666 except the charge current was set at the maximum value of 1.1 amperes per module and was not adjusted to limit the charge/discharge ratio to the specified value for 10°C of 1.04.

The temperature profile shown in Figure 1 was followed. Figures 2 and 3 are histograms of the cell voltages at different times throughout the overcharge test. At the end of the test the spread in cell voltage was small. Two of the highest cells were the replacement cells in both modules. These cells had not been subjected to a complete conditioning cycle prior to assembly in the modules. Figure 4 shows the temperature of each module throughout the test and the voltages of the two highest cells.

At the end of the overcharge test, the temperature transition to 10°C was begun starting with the discharge portion of the orbit. The cycling continued smoothly with no apparent abnormalities. The start of the taper charge occurred at essentially the same point in each orbit throughout the test. Figures 5, 6, and 7 show the charge current characteristics for orbits 10, 20 and 30. There was a slight upward trend in end of charge current and an apparent increase in end of charge voltage in some cells. These trends are considered normal for the test conditions and parameters used as described in attached correspondence dated February 20, 1970.

Following the completion of orbit # 30, the modules were discharged at 2 amperes per module to determine the residual capacity. The total capacity of the 2 modules was 11.43 ampere hours to 27.5 volts. Figure 8 shows the cell voltages at the end of the discharge.

2.8 During a 25°C electrical test there was a variation in charge current telemetry in module S/N 028. Over a period of time the charge current telemetry function exhibited a progressively increasing output for consecutive and identical test conditions. The charge current telemetry electronics circuit board from S/N 031 was used as a replacement. Examination of S/N 028 board showed the trouble to be due to an undefined instability in in a transistor.

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Table I - Test History

Date	Test	Anomaly or Remarks	Description or Results Section #
	Spare Module SN 028		
10/1/69	Thermal - Vacuum	Overcharged during minimum load orbits @ 10°C	2.1
10/26/69	T/V Preparation	Subjected to high discharge current	2.2
10/27/69	T/V	15 hour overcharge @ 10°C	2.3
10/29/69	T/V	15 minimum load orbits @ 10°C	2.3
12/18/69	Rework and Inspection	Cell #5 removed and inspected - replaced with S/N 39-47	Relay and diode replaced 2.4
12/22/69	Pulse Discharge		2.6
12/30/69	Workmanship Vibration	Results Normal	
1/9/70 1/11/70	T/V	48 hour overcharge @ 25°C	2.7
1/11/70 - 1/13/70	T/V	30 orbits @ 10°C	2.7
10/7/69	25° Electrical Test	Variation in charge current telemetry	2.8
12/19/69	Rework	Electronics circuit board S/N 033 replaced with S/N 031	
	Spare Module SN031		
10/1/69	T/V	Overcharged during minimum load orbits @ 10°C	2.1
10/26/69	T/V Preparation	Subjected to high discharge current	2.2
10/27/69	T/V	15 hour overcharge @ 10°C	2.3
10/29/69	T/V	15 minimum load orbits @10°C	2.3
11/25/69	Conditioning Cycle	Overcharged at 2 amp rate	2.5

Table I (continued)

Date	Test	Anomaly or Remarks	Description or Results Section #
	Spare Module S/N 032		
10/1/69	T/V	Overcharged during minimum load orbits @ 10 C	2.1
10/26/69	T/V Preparation	Subjected to high discharge current	2.2
10/27/69	T/V	15 hour overcharge @ 10°C	2.3
10/29/69	T/V	15 minimum load orbits @ 10°C	2.3
12/17/69	Rework and Inspection	Cells # 9 and 14 removed and replaced with S/N 43-28 and 43-15. Relay and diode replaced.	2.4
12/22/69	Pulse Discharge		2.6
12/30/69	Workmanship Vibration	Results normal	
1/9 - 1/11/70	T/V	48 hour overcharge @ 25°C	2.7
1/11/70- 1/13/70	T/V	30 orbits @ 10°C	2.7

TABLE II

COMPUTATION SHEET

NIGERIA 9 BARE SYSTEM — 15 MINIMUM LOAD BUSES — VOLTAGE DEVIATIONS BEFORE TAKE

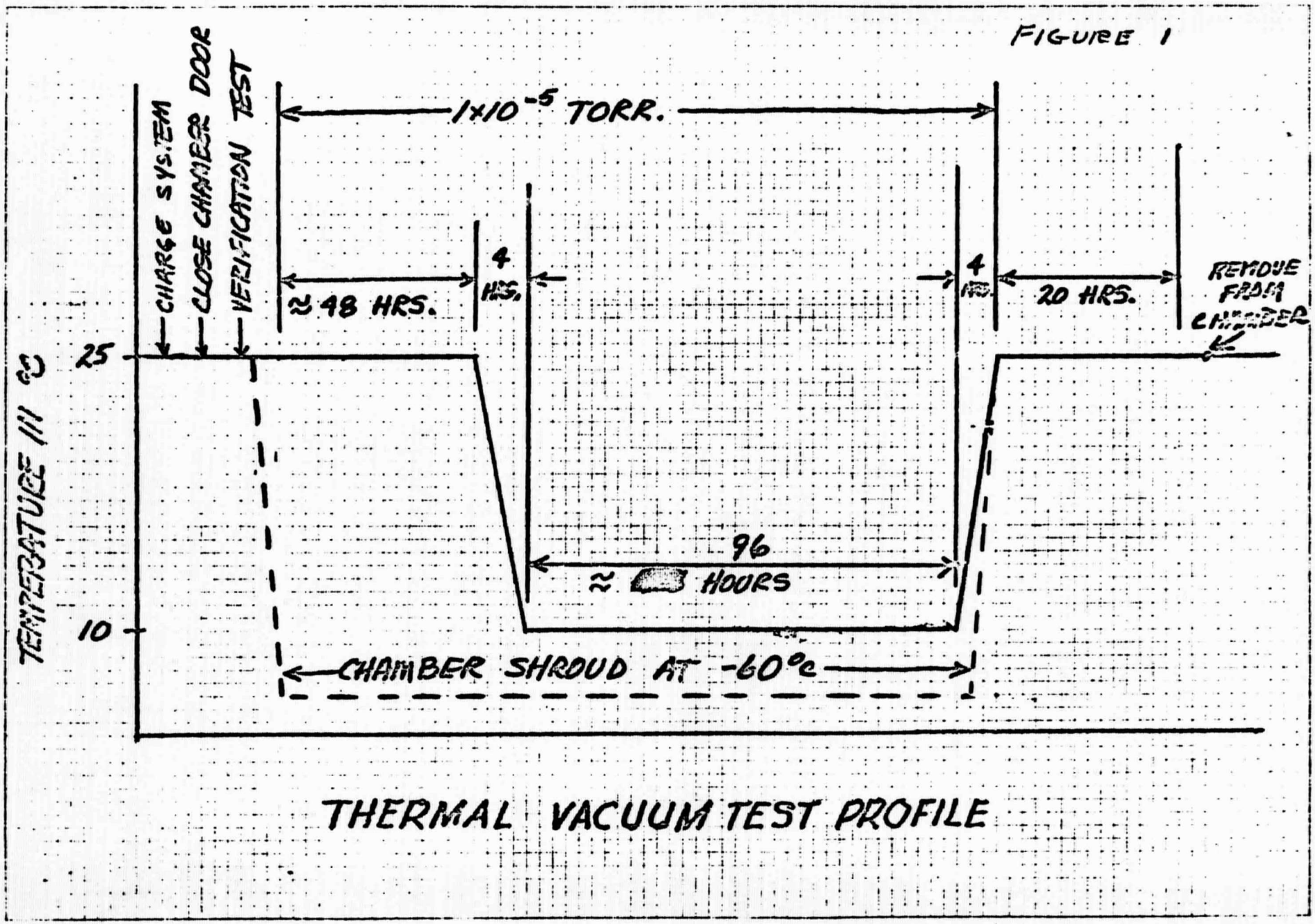
BUS	CASE NO.	PARTS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
CAF	1																	14	
	2																	54	
	3																	10	
	4																	15	
	5																	56	
	6																	47	
	7																	38	
	8																	10	
	9																	22	
	10																	21	
	11																	5	
	12																	15	
	13																	23	
	14																	6	
	15																	9	
	16																	35	
	17																	2	
	18																	16	
	19																	25	
	20																		
	21																		
	22																		
CAL	1																	55	
	2																	34	
	3																	28	
	4																	65	
	5																	24	
	6																	0	
	7																	0	
	8																	0	
	9																	64	
	10																	30	
	11																	46	
	12																	46	
	13																	11	
	14																	52	
	15																	0	
	16																	0	
	17																	42	
	18																	72	
	19																	16	
	20																	99	
	21																	12	
	22																	62	
	23																		
	24																		
CAS	1																	99	
	2																	62	
	3																	84	
	4																	84	
	5																	84	
	6																	0	
	7																	93	
	8																	30	
	9																	2	
	10																	0	
	11																	6	
	12																	92	
	13																	0	
	14																	0	
	15																	0	
	16																	0	
	17																	0	
	18																	0	
	19																	10	
	20																	0	
	21																	0	
	22																	0	
	23																		
	24																		

TABLE III

	Cell #	Initial V	032 Today V	AC Res	AC Res	Cell #	Initial V	028 Today V	AC Res	AC Res
1	42-12	1.06	.998	.006		39-43	1.05	.959	.007	
2	42-28	1.01	.986	.008		39-44	1.04	1.048	.007	
3	42-29	1.06	1.002	.007		39-45	1.09	1.052	.007	
4	42-32	1.04	.989	.007		39-46	1.08	1.086	.007	
5	43-1	1.07	1.070	.006		*39-47	1.08	1.012	.006	
6	43-5	1.06	.950	.007		39-48	1.06	1.010	.007	
7	43-9	1.07	1.088	.006		39-49	1.07	1.064	.007	
8	43-12	1.07	1.030	.007		39-50	1.05	1.003	.008	
*9	43-15		.974			39-51	1.04	.999	.007	
10	43-16	1.07	1.021	.007		39-54	1.07	1.036	.007	
11	43-17	1.09	1.047	.007		39-55	1.08	1.020	.006	
12	43-20	1.09	1.081	.006		39-56	1.07	1.067	.007	
13	43-24	1.07	1.066	.006		39-57	1.10	1.105	.006	
*14	43-28	1.02	.988	.007		39-58	1.08	1.026	.006	
15	43-31	1.07	1.030	.006		39-59	1.08	1.061	.007	
16	43-32	1.07	1.014	.006		39-61	1.07	.955	.007	
17	43-35	1.08	1.058	.006		39-63	1.05	.977	.007	
18	43-37	1.06	1.078	.006		39-64	1.10	1.091	.006	
19	43-38	1.07	1.053	.005		39-65	1.06	1.019	.007	
20	43-40	1.06	1.039	.006		39-68	1.07	1.017	.007	
21	43-45	1.09	1.080	.005		39-70	1.03	1.004	.008	
22	43-48	1.08	1.052	.006		39-72	1.08	1.006	.007	
23	43-50	1.08	1.074	.006		39-73	1.05	.969	.008	

*Replacement Cells

FIGURE 1



THERMAL VACUUM TEST PROFILE

FIGURE 2

OVERCHARGE TEST

HISTOGRAM OF CELL VOLTAGES

BATT. 1 IS S/N 028
BATT. 2 IS S/N 032

			2-20								
		2-21	2-19								
		2-18	2-05	2-12							
		2-15	1-23	2-04							
		2-13	1-20	2-03							
		2-11	1-18	2-02							
		2-10	1-15	2-01							
		2-08	1-14	1-22							
		2-07	1-13	1-19	2-14						
	2-23	2-06	1-12	1-09	1-06						
	2-22	1-21	1-11	1-08	1-05						
	2-17	1-17	1-10	1-07	1-03						
	2-16	1-16	1-01	1-04	1-02		2-09				

24 HOURS INTO CHG.

BATT 1 CURRENT = 251 MA
BATT 2 CURRENT = 336 MA.

TEMP. OF BOTH BATTERIES WAS ≈ 25°C

		2-19									
		2-13									
		2-10	2-16								
		2-04	2-15								
		2-03	2-01								
	2-22	2-02	1-22								
	2-21	1-23	1-21								
	2-18	1-20	1-19								
	2-17	1-15	1-18								
	2-11	1-13	1-16								
	2-08	1-11	1-14								
	2-06	1-10	1-08								
2-23	2-05	1-09	1-07		1-06	2-20					
2-07	1-17	1-01	1-03	1-12	1-04	1-02	1-05		2-14	2-12	2-04

21 MINUTES INTO CHG.

BATT 1 CURRENT = 816 MA
BATT 2 CURRENT = 821 MA

TEMP. OF BOTH BATTERIES WAS ≈ 27°C

1.433	1.440	1.447	1.454	1.461	1.468	1.475	1.482	1.489	1.496	1.503	1.510

CELL VOLTAGE (VOLTS)

1-15-70

FIGURE 3

OVERCHARGE TEST (CON'T.)

				2-20								
				2-19								
				2-12								
				2-10								
			2-21	2-05								
			2-18	2-01								
			2-17	1-23								
			2-13	1-22	2-04							
			2-11	1-20	2-03							
			2-08	1-16	2-02							
			2-07	1-14	1-19							
			2-06	1-13	1-09							
		2-23	1-21	1-12	1-08	2-14						
		2-22	1-17	1-11	1-06	1-05						
		2-16	1-16	1-10	1-04	1-03						
		2-15	1-15	1-07	1-01	1-02	2-09					
	1.433	1.440	1.447	1.454	1.461	1.468	1.475	1.482				

48 HOURS INTO CHG.

BATT. 1 CURRENT = 268 MA

BATT. 2 CURRENT = 337 MA

TEMP. OF BOTH BATTERIES WAS ≈ 25°C

CELL VOLTAGE (VOLTS)

1-15-70

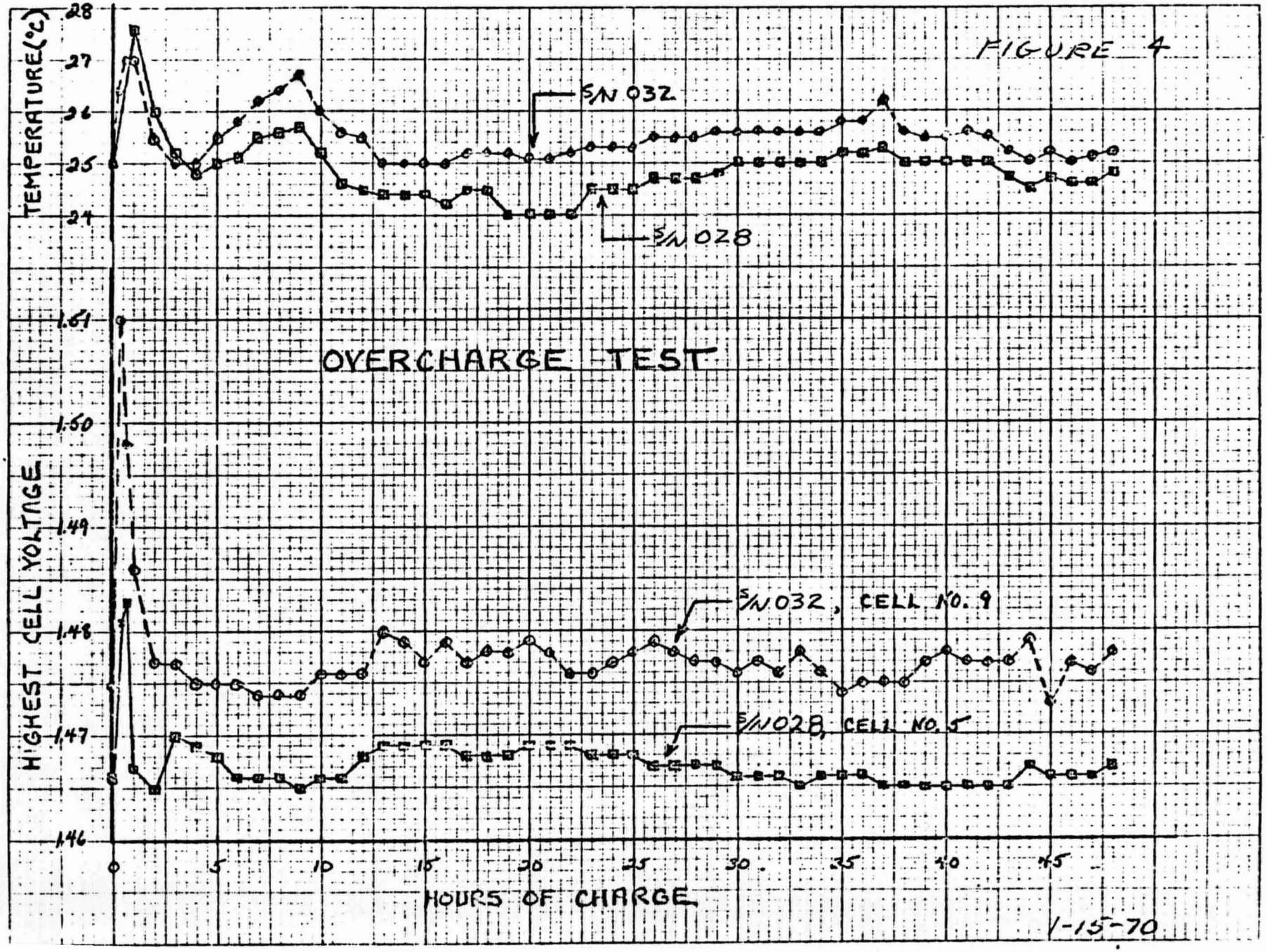
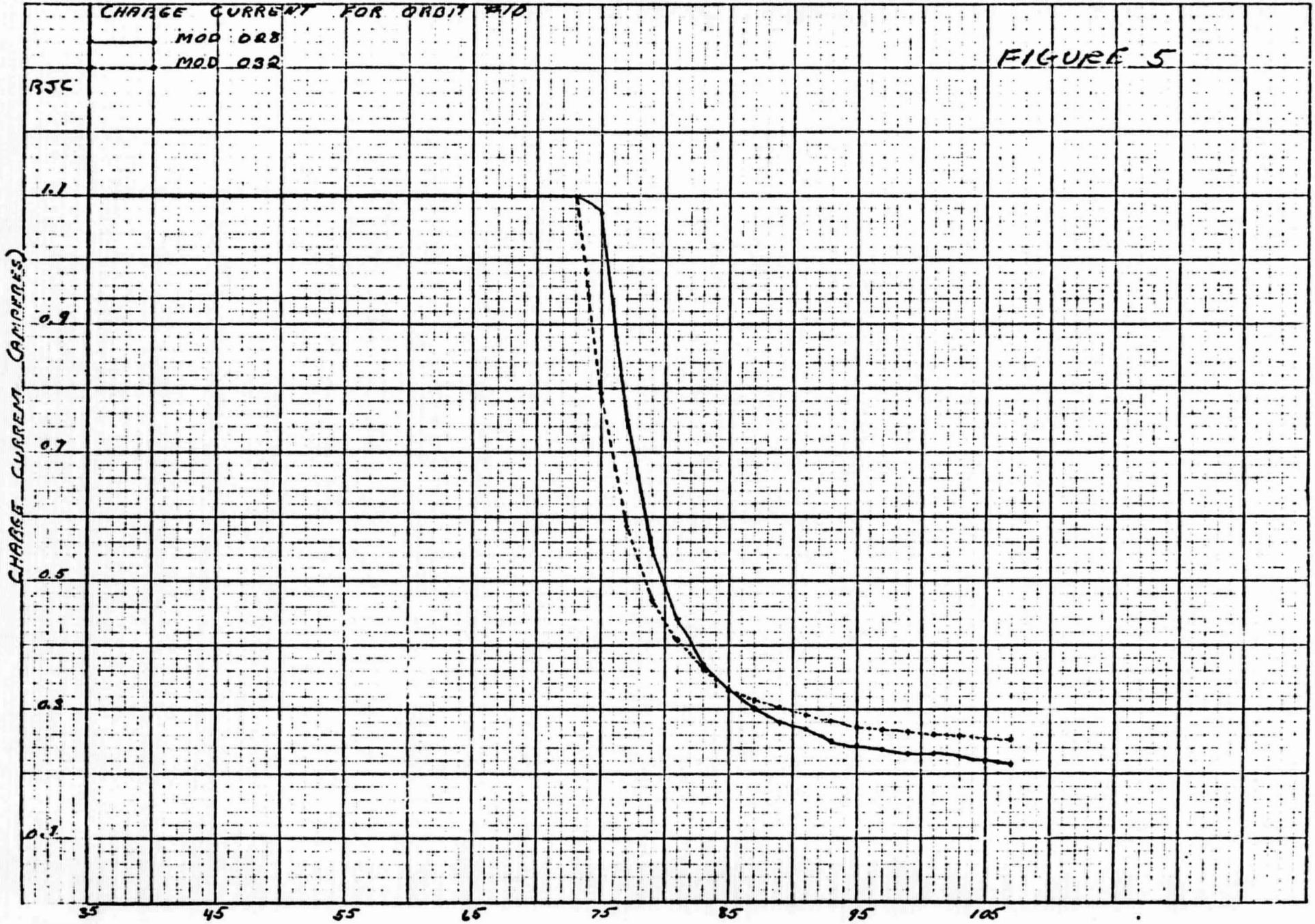
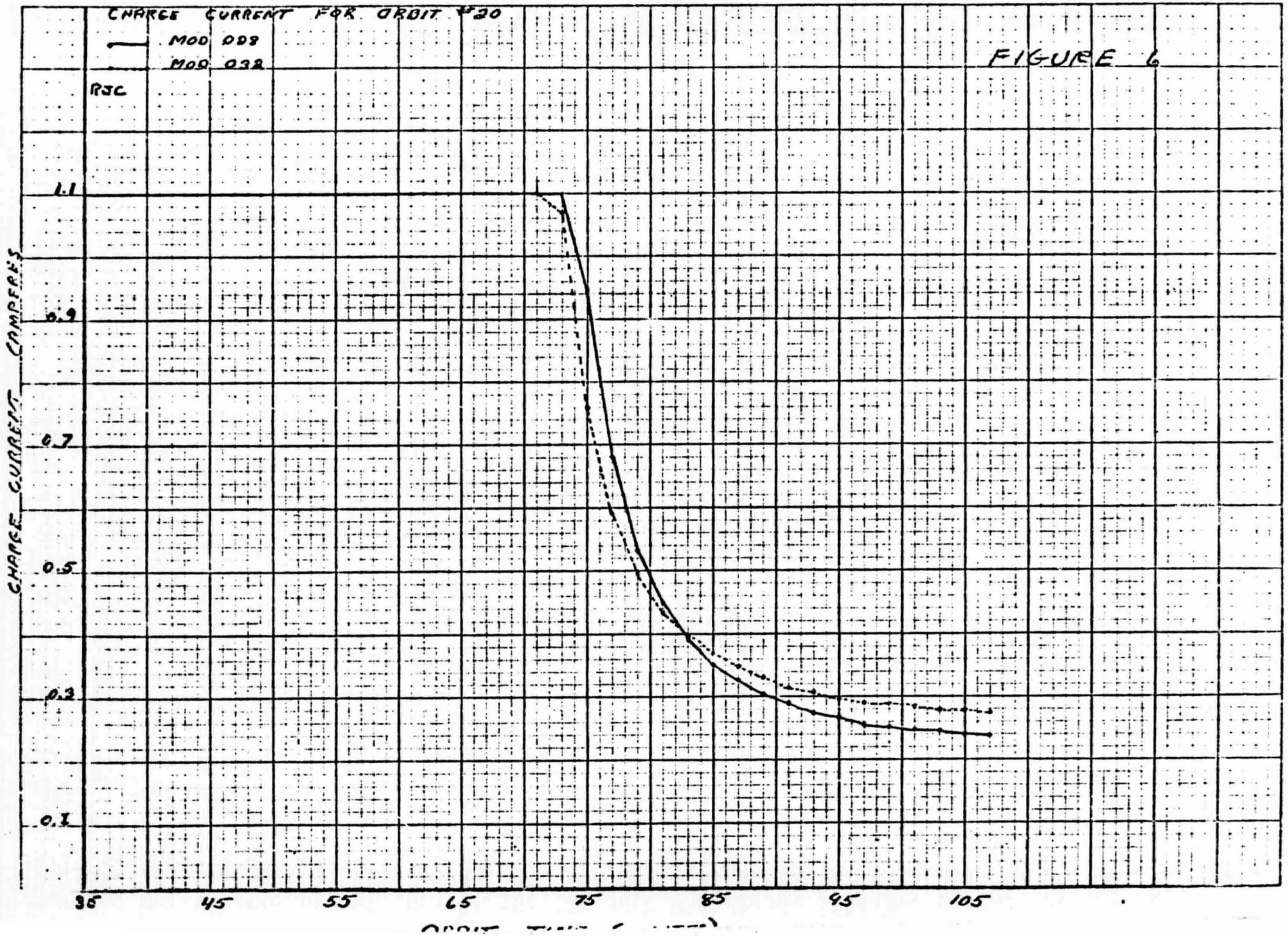


FIGURE 4
TEMPERATURE (°C)
28
27
26
25
24
S/N 032
S/N 028
OVERCHARGE TEST
HIGHEST CELL VOLTAGE
1.61
1.60
1.49
1.48
1.47
1.46
S/N 032, CELL NO. 9
S/N 028, CELL NO. 5
0
5
10
15
20
25
30
35
40
45
HOURS OF CHARGE
1-15-70


CHARGE CURRENT FOR ORBIT PID
MOD 028
MOD 032
FIGURE 5
RJC
1.1
0.9
0.7
0.5
0.3
0.1
CHARGE CURRENT (AMPERES)
35
45
55
65
75
85
95
105


CHARGE CURRENT FOR ORBIT #20
MOD 008
MOD 032
RJC
FIGURE 6
CHARGE CURRENT AMPERES
1.1
0.9
0.7
0.5
0.3
0.1
35
45
55
65
75
85
95
105

KEUFFEL & ESSER CO.

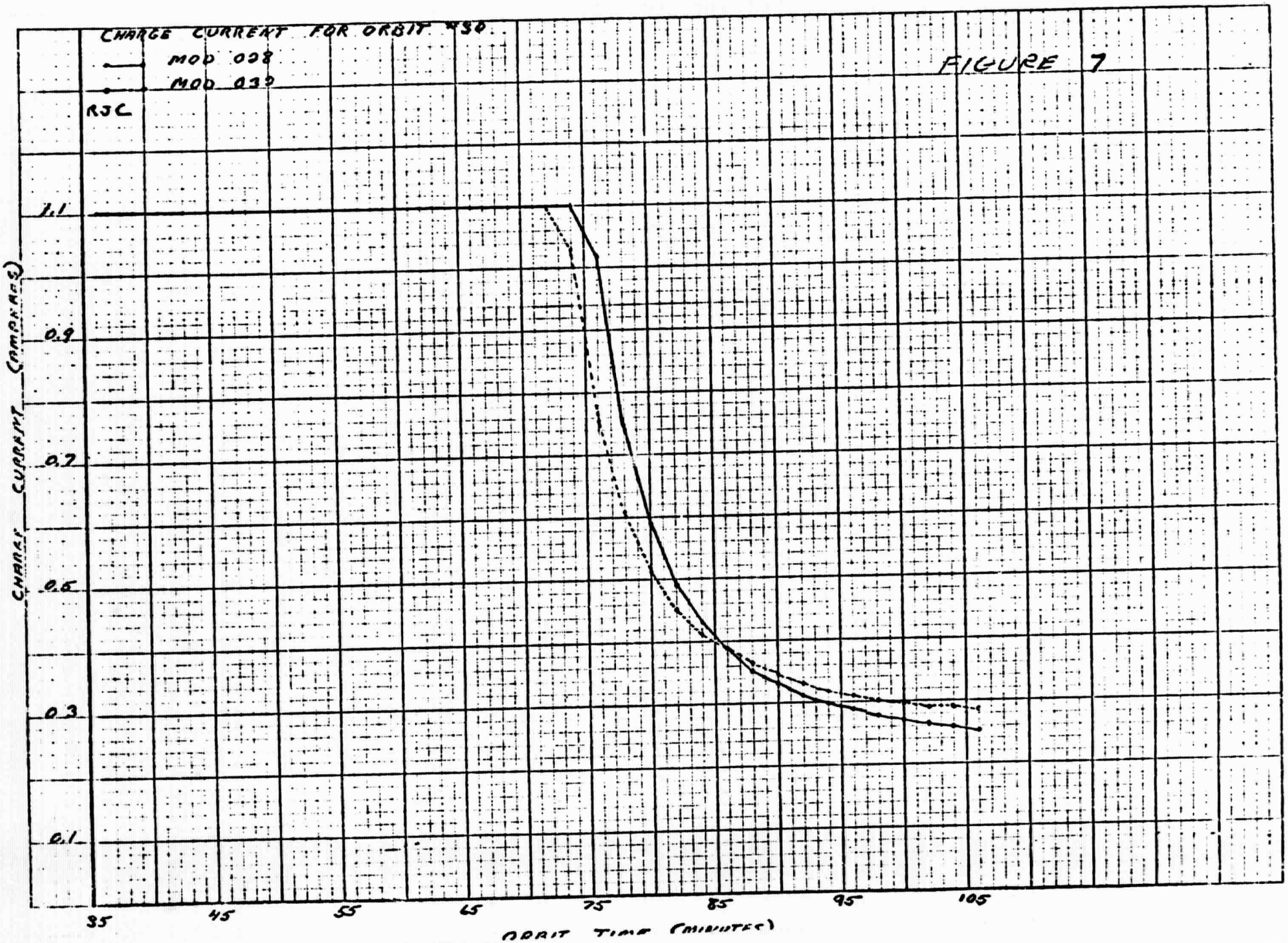


FIGURE 8

TEST →	RESIDUAL CAPACITY E.O.D. VOLTS 11.43 A.H.		SHORT TEST 20 HR. OCV	
MOD. # →	028	032	028	032
CELL # ↓				
1	1.196	1.193	1.203	1.218
2	1.196	1.187	1.203	1.218
3	1.199	1.193	1.208	1.215
4	1.202	1.187	1.201	1.216
5	1.180	1.206	1.219	1.203
6	1.194	1.198	1.206	1.199
7	1.196	1.202	1.203	1.202
8	1.198	1.205	1.206	1.201
9	1.194	1.190	1.204	1.218
10	1.194	1.190	1.202	1.203
11	1.198	1.204	1.200	1.200
12	1.199	1.195	1.201	1.205
13	1.203	1.196	1.204	1.201
14	1.199	1.194	1.205	1.225
15	1.199	1.189	1.202	1.203
16	1.179	1.190	1.202	1.202
17	1.195	1.203	1.200	1.200
18	1.195	1.203	1.202	1.203
19	1.195	1.200	1.208	1.198
20	1.195	1.187	1.204	1.203
21	1.193	1.202	1.200	1.210
22	1.199	1.201	1.205	1.201
23	1.191	1.206	1.203	1.204
E_T	27.50	27.52	27.61	27.66

RCA-AED

Subject: Increase in end-of-charge voltages during low temperature cycling of Nimbus D spare system thermal-vacuum test in accordance with Test Procedure RND-100.

Questions have been raised regarding the expected life of spare battery modules 028 and 032 because of an apparent increase in end-of-charge voltages during the 30 cycles run at 10°C. On a module basis there was no increase in voltage as shown in Figure 1. An increase in module voltage is not possible since a temperature compensated voltage limit charge control is used and the charge voltage is limited to a pre-set value. During the cycling the spread in cell end-of-charge voltages increased as shown in Figures 2, 3, and 4. The voltages of some cells increased while others decreased. This spread in end-of-charge voltage is attributed to the increased overcharge at the low temperature.

The normal charge/discharge ratio at 10°C is 1.04 while this test was configured to provide the maximum charge current of 1.1 amperes/battery at the beginning of charge with no attempt to regulate the amount of overcharge. As a result the charge/discharge ratio turned out to be in excess of 1.10 as shown in Figure 5. Prior to the overcharge period the spread in voltage was small compared to the end-of-charge. Figure 6 compares the voltages at the point where the charge starts to taper with the voltages at the end-of-charge for orbit 25.

Several cells in each module showed consistently higher end-of-charge voltages throughout the cycling. Among these were cells 5 in module 028, 9 and 14 in module 032. These were the replacement cells which were not subjected to the same previous conditioning cycles as the rest of the module.

Throughout the test the end-of-charge current showed a gradual upward trend. This trend has been seen on other cycling tests and may take several hundred cycles for the cells to equalize and the end-of-charge currents to level off. In a previous 10°C thermal-vacuum test on modules 028 and 032, prior to the overcharge and high surge current stresses, this same trend was observed. Figure 7 shows the end-of-charge currents during the 10°C thermal-vacuum test performed in August 1969. This test followed the standard procedure of TP-SFTV-1846666 in which the charge/discharge ratio was limited to 1.04 by limiting the initial charge current.

In summary, the trends noted in the data appear to be normal for a battery cycled under the parameters of this test and the cell variations are of such small magnitude as to be insignificant. With the limited data available there is nothing to indicate an abnormal condition which would affect the life of modules 028 and 032.

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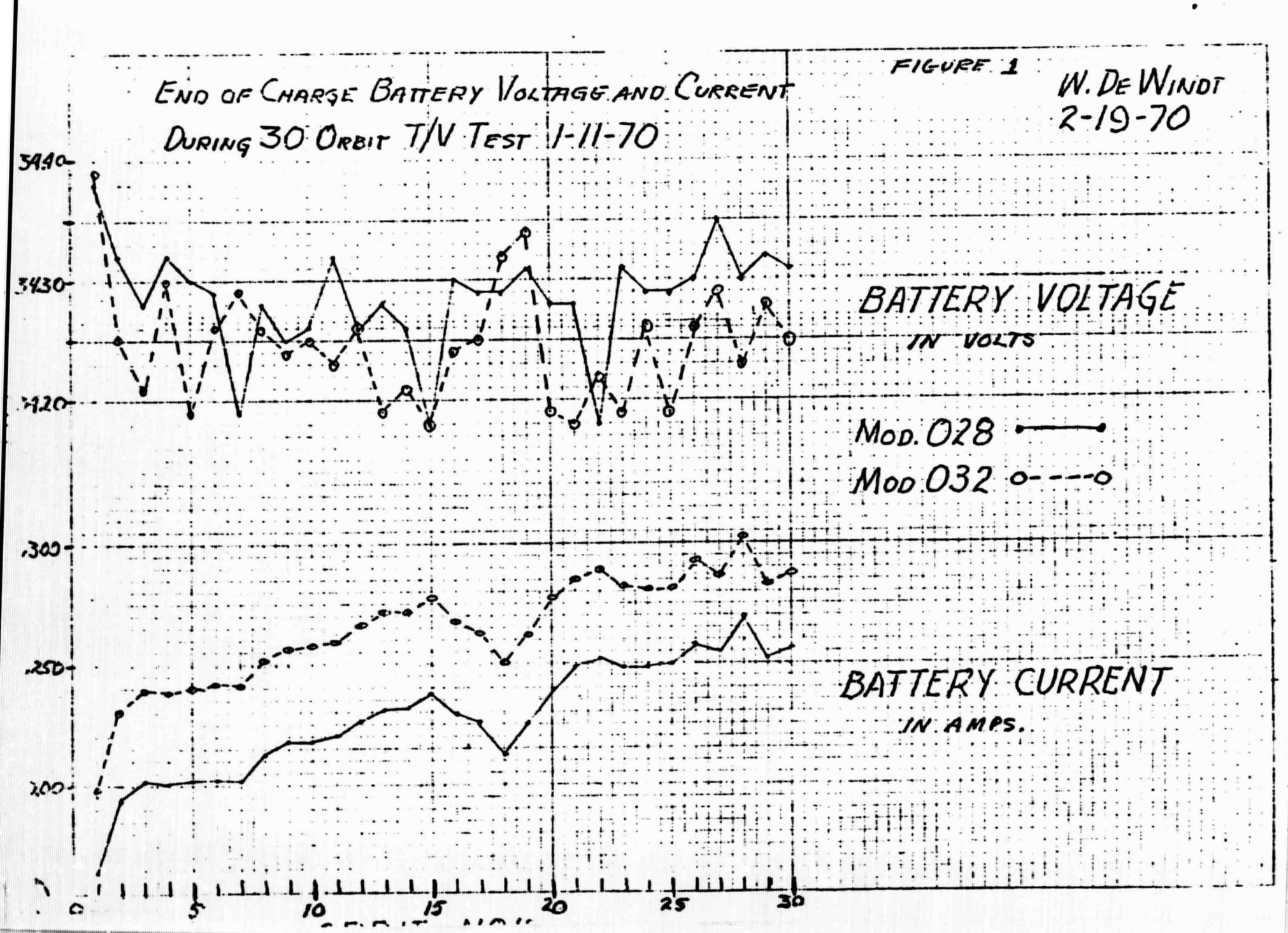


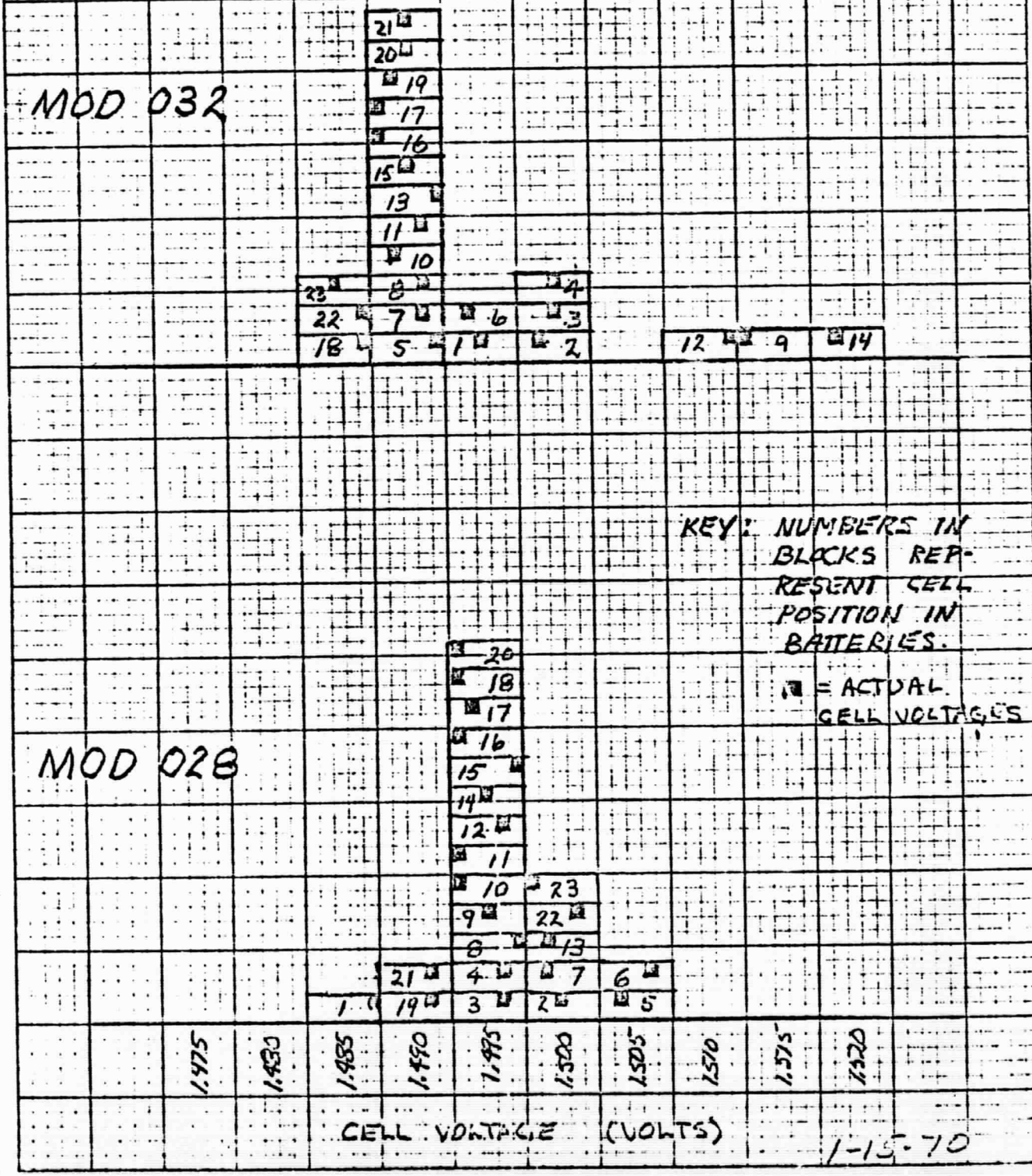
FIGURE 1
W. DE WINDT
2-19-70
END OF CHARGE BATTERY VOLTAGE AND CURRENT
DURING 30 ORBIT T/V TEST 1-11-70
3490
3430
3420
300
250
200
0
5
10
15
20
25
30
BATTERY VOLTAGE
IN VOLTS
MOD. 028
MOD 032
BATTERY CURRENT
IN AMPS.

ORBIT #1 END OF CHARGE CELL VOLTAGES

MODULE 028 & 032

TEMP ≈ 9°C

FIGURE 2



1-15-70

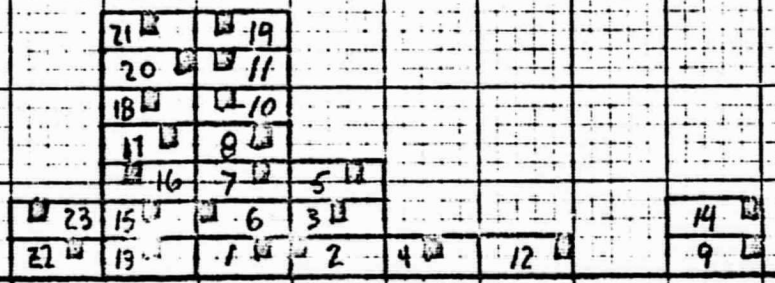
ORBIT #15 END OF CHARGE VOLTAGES

MODULES 028 & 032

TEMP. ≈ 11°C

FIGURE 8

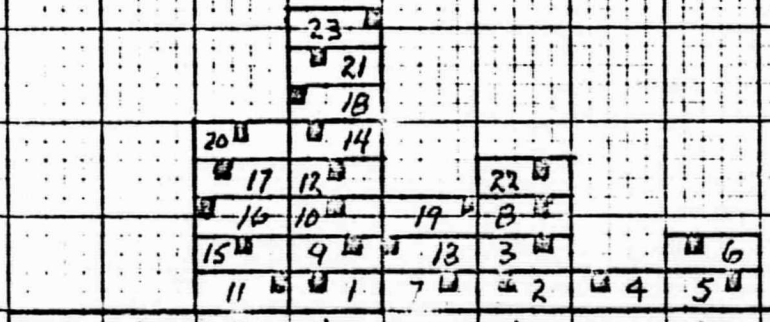
MOD 032

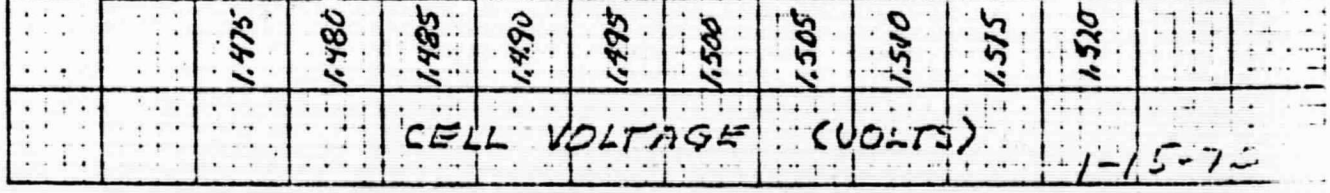


KEY: NUMBERS IN BLOCKS REPRESENT CELL POSITION IN BATTERIES.

■ = ACTUAL CELL VOLTAGES

MOD 028





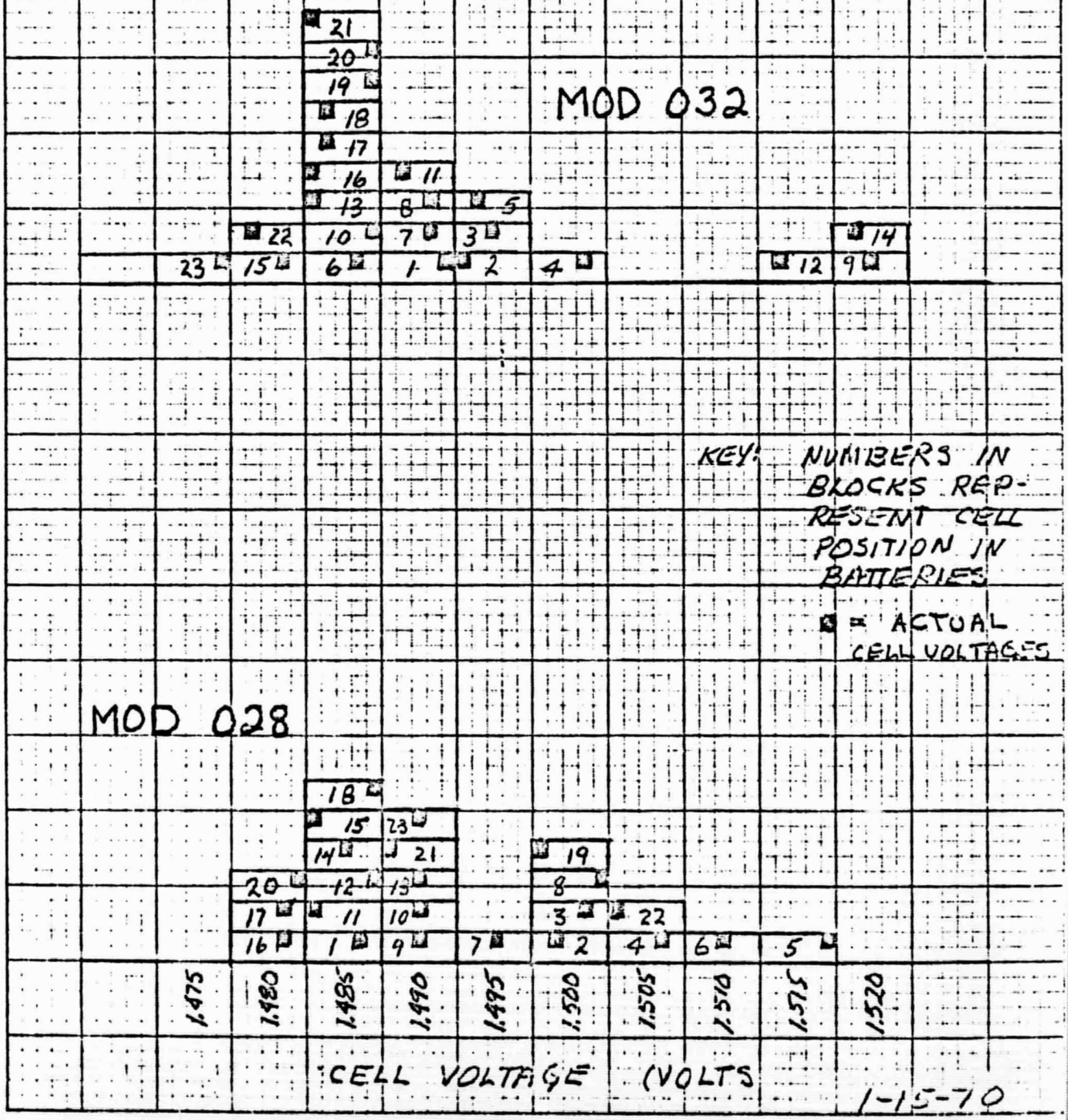
1-15-72

ORBIT #30 END OF CHARGE VOLTAGE

MODULES 028 & 032

TEMP ≈ 9°C

FIGURE 4



1-15-70

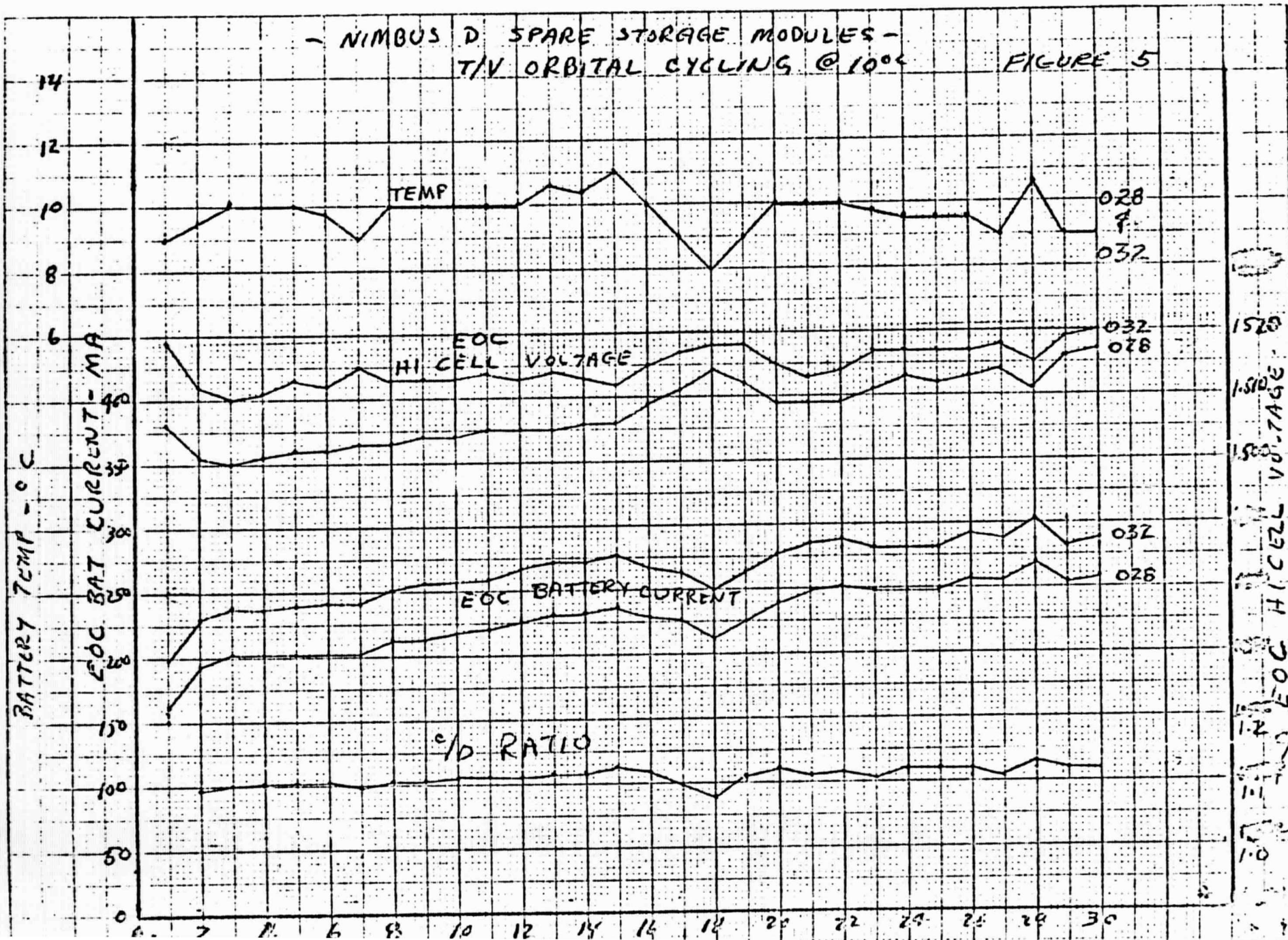
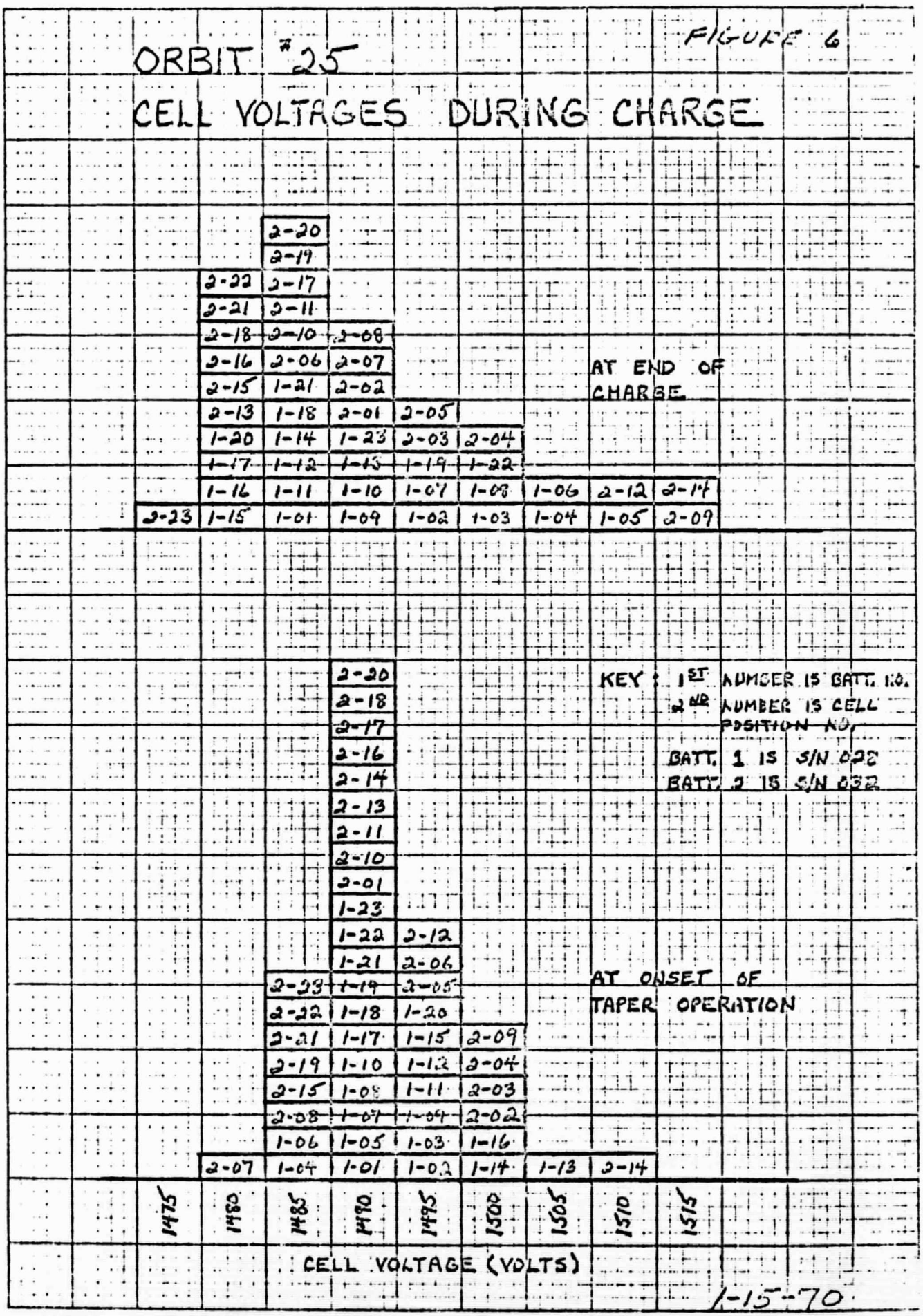


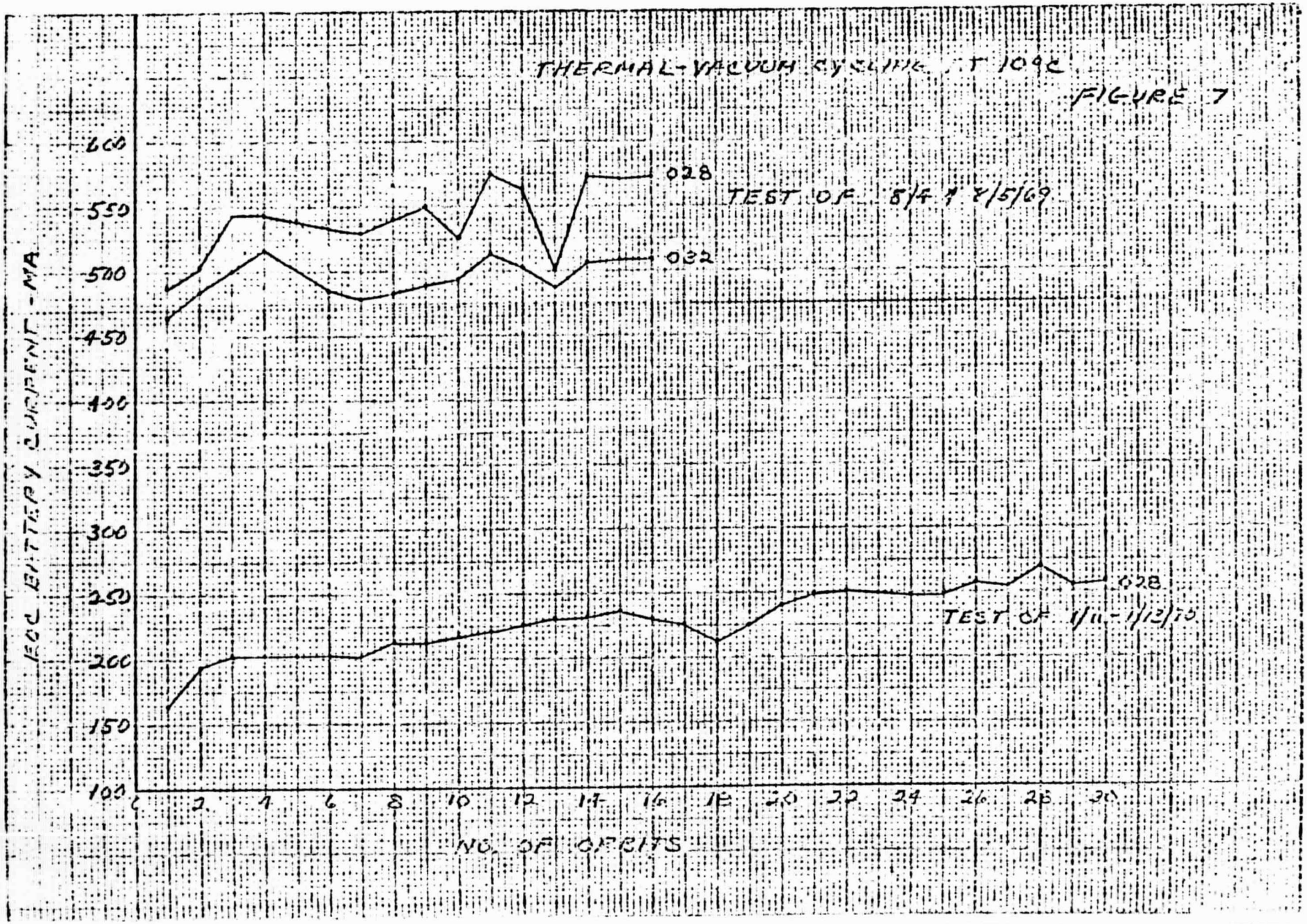
FIGURE 6

ORBIT #25

CELL VOLTAGES DURING CHARGE



1-15-70


THERMAL-VACUUM CYCLING T 109E
FIGURE 7
028
TEST OF 8/4 & 8/5/69
032
028
TEST OF 1/11 - 1/12/70
LOAD BATTERY CURRENT - MA
600
550
500
450
400
350
300
250
200
150
100
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
NO. OF ORBITS

INTERNAL CORRESPONDENCE RCA

TO: R. Newell DATE: 16 January 1970

FROM: R/QAE R&QAE-1/70 - Nimbus

SUBJECT: Assessment of Relays Associated with Nimbus D Storage Module Current Faults

Ref: 1) TDR's 6503 and 6881

2) Babcock Relay K1 per 1721945

3) Schematic 1759588, Nimbus D Battery Module Electronics Schematic

Though the three relays, one each in storage modules S/N's 028, 031, and 032, were normally functional after experiencing the accidental short-circuit currents described in the two referenced TDR's, they were replaced since the peak currents associated with the faults might have been as high as 150 amperes in contrast to their 10 ampere contact rating. Uncertainties relative to current-time profiles and numbers of "makes" or "breaks" were additional compelling factors toward their removal.

The replacement of the relays was of itself both necessary and sufficient relative to parts reliability. However, there was an interest in the condition of the removed parts. This was assessed by electrical and visual inspections and is described as follows:

The relays do not show any abnormality. Qualitatively, visual mic roscopic contacts inspection disclosed no more than that the contacts are not virgin and also were not abused. There are no significant differences in discoloration exhibited between the normally used 2-to-4 contact pairs, one of which was involved in a total battery short-circuit, and these pairs are not significantly different in appearance from the 5-to-7 pairs, all of which were involved in the 15-cell tap-off shorts. Quantitatively speaking, all measured contact pair resistances, used and unused, were 3.8 to 4.0 millichms except one 2-to-4 used pair which was 5 millichms. All contact pair resistances are well within their 10 milliohm maximum specification, and the 1 milliohm difference exhibited by the 5 milliohm 2-to-4 contact pair is not considered significant.

The inspection and test results give no insight into the nature of the overall module's experience (had a contact been fused or opened, something quantitative could possibly have been formulated); rather, the results tell more about the relays than the modules: the relay contacts can withstand appreciable overload and, relative to the 15-cell tap-off clearing function, they are admirably suitable.

Photographs of the contacts were not considered as significantly contributory to the above described visual examination results, and were not taken.